

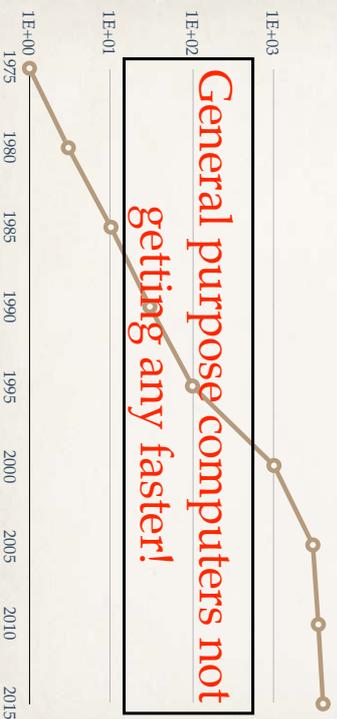
Computer System Synthesis

Vijay Nagarajan & Boris Grol



1

End of transistors scaling



3

End of transistor scaling



2

The Age of Specialisation...



Graphics	
Machine learning	
Vision	
Data centre	

4

Specialisation Problem

* Given a new application domain, how to specialise the system stack?

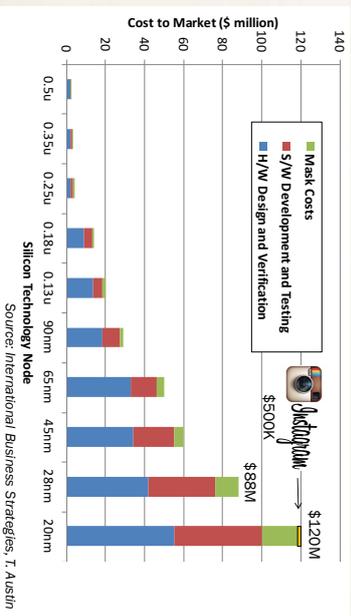
Specialisation Problem

* Given a new application domain, how to specialise the system stack?

In-Datcenter Performance Analysis of a Tensor Processing Unit™
 Norman P. Jouppi, Cliff Young, Nishant Paul, David Patterson, Gregory Anselmi, Raminder Bajwa, Sarah Bave, Suresh Bhatia, Nan Bholani, Albert Bershad, Rick Borde, Pereshwari Chand, Clifford Chan, Chieh-Clark, Jeremy Cornell, Mike Dabry, Matt Dan, Jeffrey Dean, Ben Cohen, Tara Venk, Ghaemmaghnam, Jasrinda Gargant, William Groland, Robert Hagmann, C. Richard Ho, Dong Hoang, John Hu, Robert Hundt, Dan Hurt, Julian Ibarz, Aaron Jeffrey, Ark, Jaworski, Alexander Kaplan, Harshil Khaitan, Andy Kohli, Navson Kumar, Steve Lacy, James Laudon, James Law, Derrin Lee, Chris Lery, Zhiyuan Liu, Kyle Luke, Alan Lunin, Gordon Macken, Adriana Magescu, Maire Mahony, Keran Miller, Rahul Nagarajan, Ravit Narayanswami, Roy Ni, Kathy Ni, Thomas Norrie, Mark Omernick, Narayan Pendakonda, Andy Phelps, Jonathan Ross, Matt Ross, Amir Shalek, Ernie Smedhini, Chris Seven, Gregory Shalov, Matthew Snelman, Jed Sauer, Dan Scheper, Andy Shing, Mercedes Tan, Gregory Thorson, Ben Tian, Tommi Tom, Erik Tjuck, Yijia Vasudevan, Richard Walter, Walter Wang, Eric White, and Dae Hyun Yoon
 Google
 Email: {njouppi, cliffey, nishantp, davidp, ghaemmaghnam, raminderb, sarahb, sureshb, nanb, albertb, bershad, rickb, pereshwari, cliffordc, chan, chieh-clark, jeremy, cornell, mikedabry, mattd, dan, jeffrey, dean, ben, cohen, tara, venk, ghaemmaghnam, jasrinda, gargant, william, groland, robert, hagmann, c, richard, ho, dong, hoang, john, hu, robert, hundt, dan, hurt, julian, ibarz, aaron, jeffrey, ark, jaworski, alexander, kaplan, harshil, khaitan, andy, kohli, navson, kumar, steve, lacy, james, laudon, james, law, derrin, lee, chris, lery, zhiyuan, liu, kyle, luke, alan, lunin, gordon, macken, adriana, magescu, maire, mahony, keran, miller, rahul, nagarajan, ravit, narayanswami, roy, ni, kathy, ni, thomas, norrie, mark, omernick, narayan, pendakonda, andy, phelps, jonathan, ross, matt, ross, amir, shalek, ernie, smedhini, chris, seven, gregory, shalov, matthew, snelman, jed, sauer, dan, scheper, andy, shing, mercedes, tan, gregory, thorson, ben, tian, tommi, tom, erik, tjuck, yijia, vasudevan, richard, walter, walter, wang, eric, white, and, dae, hyun, yoon}

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Cost sifting Innovation?



Source: International Business Strategies, T. Austin

Synthesise computer systems?

Computer Systems Synthesis

- * Machine learning for Systems
- * Iterative compilation

Using Machine Learning to Focus Iterative Optimization

F. Ayubov, E. Bonilla, J. Croston, B. Finkle, G. Frustin,
MFB, O'Boyle, J. Thomson, M. Toussaint, C.K.L. Williams
School of Informatics
University of Edinburgh
UK

9

Computer System Synthesis?

- * Machine learning for Systems @Edinburgh
- * Iterative compilation
- * Runtime parameter **Can Correctness?**
- * Microarchitecture design space exploration
- * Benchmark generation
- * Source code analysis

11

Computer System Synthesis

- * Machine learning for Systems @Edinburgh
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10

Challenge: Correctness

- * Correctness a fundamental component of systems
- * Bugs are costly!
 - * Intel floating point bug, Transaction bug, ARM coherence bug,
 - * Post-hoc validation expensive!
- * Can we have correct by construction?

12

System Synthesis: Formal Methods?

- ✦ PL/Verification community has made tremendous recent progress on program synthesis techniques
- ✦ Given a program specification, and a partial implementation, fill in the rest
- ✦ Spreadsheet learning by example, biological models, SQL queries.
- ✦ On-going work:
- ✦ Cache coherence protocol synthesis
- ✦ Robot controller synthesis

13

Computer Systems Synthesis

- ✦ The age of specialisation!
- ✦ Low cost computer system design key to future innovation
- ✦ New techniques: Machine learning + formal methods

15

ML + Formal Methods?

- ✦ Synthesise partial implementation (ML) + fill up the result using formal methods?
- ✦ Some on-going work on the ML side. E.g. Work out of microsoft research on Deep learning for program synthesis.

14

Researchers and Activities

- ✦ Researchers who have informally evinced interest
 - ✦ Bhatotia, Elessamni, Fleuriot, Grot, Jackson, Leather, Nagarajan, O'Boyle, Ramamoorthy, Stark, Sutton, Topham
- ✦ Activities
 - ✦ 1 or 2 pilot workshops to identify shared vision.
 - ✦ If researchers are still interested to continue, then carry on with programme.
 - ✦ Monthly reading group with above researchers and students
 - ✦ Annual 1-day research retreat, in a topic of common interest (e.g. brainstorming for a proposal)

16